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Technological Innovation and Organizational Learning: a case study on dynamics of a technological innovator network

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1. INTRODUCTION

Understanding the role of knowledge and organizational learning in fostering or inhibiting innovation becomes crucially important (Lam, 2005). Innovation is not an isolated process of neither individuals nor firms. Innovation is a process which happens in a system where interaction between firms, customers, suppliers, competitors and various other private and public organizations is important (Fagerberg, 2005). It is impossible to understand innovation processes without going deeper into the understanding of learning and knowledge and it is blind to explain economic performance without bringing into the analysis of social relationships and organizational structures (Lundvall and Christensen, 2004). Knowledge creation, knowledge sharing and knowledge application which are crucial to technological innovation highly depend on social interaction in the circumstance of technological uncertainty and complexity. Now the time has come to open up the black box of social interaction through focus on how learning takes place in the real world (Lundvall and Christensen, 2004).

Social context and economic environment should be highly recognized when studying innovation and organizational learning. Researches have been done according to various observations, explanations have been made in the light of diversified theories. But do they fit Chinese context? Powell and Grodal (2005) argued that when science and technology developed rapidly and the sources of knowledge are widely distributed, networks can foster innovation. But when technology doesn't change very quickly, will networks help to innovate? Pavitti (2005) identified two generic processes of innovation that is coordinating and integrating specialized knowledge and learning under conditions of uncertainty. But this conclusion is also deduced from his research which focuses mainly on large firms within the USA, Europe, and Japan. Will the underdeveloped area has any different process of innovation? When talking about challenges for innovation theory and research, Lundvall

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and Christensen(2005) considered one implication of the important role of innovation's social dimensions is that it is difficult to develop a general theory of innovation and interactive learning. They pointed out that the processes involved are highly context dependent and the best we can do is to develop models that bring to the fore differences in context as different patterns.

This paper is about the dynamics of technological innovator network (TIN) in the past ten years in a state-owned company named Grace Corporation in southwest China. It tried to understand the pattern and process of organizational learning for technological innovation in the perspective of social network. The social context and economic environment of relatively underdeveloped southwest China were considered as important background and influencing factor of what has happened.

This paper focuses on technological innovation and organizational learning of a state-owned company in relatively underdeveloped southwest China. We try to find out how the TIN evolutes in the ten years of technological innovation and how to accelerate organizational learning across functional and organizational boundaries to foster innovation. We adopted Social Network Analysis (SNA) to map and measure the relationships between different departments and organizations inside and outside of the company. Case study was used as our main research method. We hope this research can show us a picture of the dynamics of TIN in this firm in order to get deeper insights into how organizational learning impacts technological innovation. We also hope it can provide some valuable views for firm managers and policy makers.

We addressed four research questions:

1. What stages did technological innovation in Grace go through in the past ten years?
2. How did the TINs of Grace look like in these stages?
3. How did the TINs of Grace evolve over the stages of technological innovation?
4. How to accelerate organizational learning across functional and organizational boundaries to foster technological innovation at present?

2. RESEARCH BACKGROUND

2.1 What are the concepts of technological innovation, organizational learning, social network, and network dynamics in this paper?

Technological innovation in this paper refers to innovation in technological aspect including product innovation which are new or better material goods as well as new intangible services, and process innovation which are new ways of producing goods and services (Edquist, 2005). Innovation is a process of bring new problem –solving ideas into use (Amabile 1988; Kanter, 1983). Innovative organization is the one who is capable of effective learning (Senge,1990; Agyris and Schon, 1978) and creating new knowledge (Nonaka, 1994; Nonaka and Takeuchi, 1995).

Organizational learning in this paper is about competence building of the firm. There is no consensus definition of organizational learning. Argyris and Schon(1978), two of the early researchers in this field, defined organizational learning as "the detection and correction of

error". Fiol and Lyles (1985) define learning as "the process of improving actions through better knowledge and understanding". Dodgson (1993) describes organizational learning as "the way firms build, supplement, and organize knowledge and routines around their activities and within their cultures and adapt and develop organizational efficiency by improving the use of the broad skills of their workforces". Huber (1991) states that learning occurs in an organization "if through its processing of information, the range of the organization's potential behaviors is changed". Schwandt & Marquardt (2000) explicitly render the need to understand organizational learning as relational phenomena. Different researchers study it in different perspective and embed it in different school of thoughts. In this paper we considered organizational learning as a process which takes place through activities performed by individuals, groups, and organizations as they gather, interpret, and store information, imagine and plan new actions, and implement change. We consider it as a conscious attempt on the part of organizations to retain and improve competitiveness, productivity, and innovativeness in uncertain technological and specific social circumstances.

Social network in this paper is combined by intrafirm network and interorganizational network. Network is a set of nodes connected by a set of ties. Nodes are the actors or players of the network. In the intrafirm network of this paper, the nodes are groups of people who serve in different functional department such as marketing, financial, R&D, HR, etc. within the firm. In the interorganizaitonal network of this research, the nodes are formal structures that are consciously created and have an explicit purpose (Edquist and Johnson 1997). They are oraganizational actors such as educational and scientific research institutes, non-governmental investment institutions, customers, competitors etc. Ties are the relationships between the nodes. In this research the ties are undirected and unweighted. Lundvall (2007) argued the impact of innovation on economic performance will typically depend upon changes in “people”, “orgware” which refers to how people relate to each other within organizational borders, and “socware” which refers to how people relate to each other across organizational borders. The “orgware” and “socware” he refered to can be interpreted as the structural attribution of intrafirm network and interorganizational network in this paper.

Technological innovator network (TIN) in this paper refers to network of innovators (Powell, 2004) rather than network of innovation (Tuomi, 2002). The former is a homogeneous network in which the nodes are different levels of people/organizations and the ties are formal or informal relations. The latter is a heterogeneous network in which the nodes can be either people/organizations or technologies and the ties can be either relations or adoptions of technologies by organizations.

Network dynamics in this paper refers to the evolving or changing structure of the network, such as breaking or making of ties. We tried to take snapshots for the TIN during its evolutionary process in the past ten years. We ignored the dynamics on the network which means the change of the actors themselves.

2.2 How are the relationships between technological innovation, organizational learning, and social network in literatures?

2.2.1 Technological innovation and organizational learning

Technological innovation process is a diversified learning process. Learning within and across organizational borders has a major impact on innovation. Learning may come from learning-by-using (Rosenberg, 1982), learning-by-doing (Arrow, 1962a), and learning-by-interacting (Lundvall, 1985;Lundvall and Vinding, 2004). The concept of learning-by-interacting pays more attention to the social attributes of learning. Learning may arise from internal or from external sources of knowledge (Dogson, 1991). External learning refers to the absorption capacity of firms (Cohen and Levinthal, 1990).

Organizational learning promotes creativity and innovation. This has already been asserted by famous scholars in the field of knowledge management such as Argyris, Schon, and Senge. Saban et al. (2000) also argued that organizational learning is a critical component to innovation when he studied the process of new product development. He pointed out that before a company can improve its innovative behavior, management must analyze its current organizational learning.

The nature of organizational learning and technological innovation are consistent with each other. 1) Learning process is uncertain because what needs to be learned about transforming technologies and accessing markets can only become known through the process itself (Lazonick, 2005). Technological innovation process is also uncertain. The evolution of technologies contains great technical uncertainties, including the uncertainty of scientific basis, technical application, technical standards, functions and benefits, and technical lifecycle (Liu and Li, 2005). Innovation is inherently uncertain, given the impossibility of predicting accurately the cost and performance of a new artifact, and the reaction fusers to it (Pavitt, 2005). 2) Learning process is cumulative because what is learned today provides a foundation for what can be learned tomorrow. Where firms search for the future is heavily conditioned by what they have learned to do in the past (Georghiou et al., 1986). Technological innovation process is also cumulative because it can't be done all at once. Technological change is a cumulative process and depends on the history of the individual or organization involved (Dosi, 1988). 3) Learning process is collective because it requires collaboration of different people with different capabilities. Technological innovation process is also collective. Given the increasingly specialized and professionalized nature of the knowledge on which they are based, firms are path-dependent (Pavitt, 2005). Knowledge specialization is a must for the organizations to effectively learn diversified knowledge of technologies. It is hard for every single organization to learn the various specialized knowledge without relevant knowledge background (Grant and Baden-Fuller, 2004). When technology-fusion becomes more and more typical in the occurring and developing process of technologies, less and less signal individual and organization has the capability to innovate isolatedly.

2.2.2 Organizational learning and social networks

Organizational learning is a social event (Cohen and Prusak, 2001) in which a group of people along with their shared resources and dynamic relationships assemble to make use of shared knowledge in order to enhance learning and create new knowledge. Organizational learning has been viewed as a process by which organizations as collectives learn through interaction with their environments (Cyert & March, 1963). Organizational learning addresses how organizations adapt to their environments, create new knowledge, build core competences, and then achieve competitive advantage. Social networks of organizational learning contribute significantly to the innovative capabilities of firms by

exposing them to novel sources of ideaes, enabling fast access to resources, and enhancing the transfer of knowledge (Powell and Grodal, 2005). The outcome of learning processes will depend on social relationships such as trust, authority and recognition. Therefore, the broader societal and socio-economic context needs to be taken into account when analyzing the formation of network relationships (Lundvall, 2005).

Social network can provide diversified knowledge resources for organizational learning. Either intraorganizatonal or interorganizational relationships lead to various benefits relating to knowledge diffusion, knowledge sharing, access to specialized knowledge, and intra- and inter-organizational learning. Organizations with border networks make organization expose to more experiences, various competencies and added opportunities (Beckman and Haunschild, 2002). By having access to a more varied set of activities, experiences, and collaborators, companies broaden the resource and knowledge base that they can draw on (Powell and Grodal, 2005). Network relationships and relational contracting are very frequent because they are the most effective institutional form when it comes to reaping benefits emanating from interactive learning (Lundvall and Christensen, 2004).

2.2.3 Technology innovation and social network

Technology innovation process is more likely to be considered as a social event rather than technological phenomenon at present. In the recent innovation research an increasing number of scholars are paying attention to the organizational side besides the technological aspect of innovation. Technological innovation becomes a social phenomenon because it is a combination of uncertainty and interaction (Lundvall and Christensen, 2004).

Social network is now not an environmental element but the main component of innovation system. This can be seen in the progressive inclusion of social ingredients into theories of knowledge-based innovation. When talking about the two characteristics of product innovation, Lunvall and Christensen (2004) argued that product innovation is a process where the outcome is highly dependent upon interaction and communication between people. The reason is that when innovating individuals need to seek and share resources they need to do it with the others and the process of knowledge sharing as well as the process of knowledge creating will happen in the very process of interaction. The interaction can just happen in a relationship structure that is the social network.

3. RESEARCH METHODOLOGY

When study the complicated dynamics of technological innovator network (TIN) there is no single method which is competent. Methodological individualism cannot be applied to processes where knowledge and learning are central (Arrow, 1994). Case study method and social network analysis were adopted in this paper. We tried to use multiple tools to see dynamics of the TIN clearly and deeply.

3.1 Case study methodology

Case study methodology was used to understand the major issues surrounding the organizational learning and technological innovation in Grace. In organizational research,

the case study method is one of the frequently adopted research methods, and the appropriateness of the method is well documented (Eisenhardt, 1989; Pettigrew, 1990). Different sources of evidence are utilized, including questionnaire, interviews, direct observation, archives and statistics.

In the data collection phase, we used one questionnaire, which is to collect the relational data of the TIN of Grace. We paid another two visits to Grace this year besides the previous four visits in the past two years. 25 interviews were done in total. The interviewees were the president and chairman of the board, the vice-general manager, the directors of the middle-level management team from seven different sections including the Science and Technology Administration Department, the Domestic Marketing Department, the International Marketing Department, the Strategic Planning Department, the IPR Office, the HR Department, and the Real Estate Company. We also interviewed the engineers and the workers. Typically each interview lasted for 1 to 2 hours at the old location of Grace as well as the new site. The interview phases lasted 8 non-consecutive weeks. All of the interviews were well recorded but not taped since the informants were reluctant to share their views on record. An agreement was signed to give a promise of Grace's business secrecy. Informal discussions with the members of the organization provided us with a better understanding of the important themes underlying the firm's practice of organizational learning and technological innovation.

In the data clarification and complementation phase, we contacted Grace's managers via email correspondence and telephone discussions for further information and data, and to clarify unclear points in the previous interviews.

3.2 Social network analysis

Social network analysis (SNA) was adopted as the analytical tool in our research in consideration of the interaction-dependence of technological innovation and social attribute of organizational learning.

The social network perspective encompasses theories, models, and applications that are expressed in terms of relational concepts or processes (Wasserman and K. Faust, 1994). Social network analysis focuses on uncovering the patterning of people's interaction. It is based on an assumption of the importance of relationships among interacting units and on the intuitive notion that these patterns are important features of the lives of the individuals who display them. Network analysts believe that how an individual lives depends in large part on how that individual is tied into the larger web of social connections. Many believe, moreover, that the success or failure of societies and organizations often depends on the patterning of their internal structure.

The software of NetDraw and Ucinet was used to map the TIN of Grace and detect the attributes of this network in order to understand the pattern and dynamics of it. Four concepts were used in network analysis in this paper to detect the attributes of the network structure. They are density, centrality, betweenness, efficiency, and diversity.

4. CASE DESCRIPTION

This paper is based on observations of innovation activities in a state-owned textile company named Grace Corporation based in southwest China. We have tracked this company for three years.

Yibin Grace Group Limited Corporation is located in Yibin city of Sichuan province in southwest China. It grows out of a small chemical fiber factory founded in 1984. Till 1997 it was still a small factory on the edge of bankruptcy. 1997 was a milestone in the history of Grace marked by the change of top management and the invention of a revolutionary technology named "2S". Since then Grace experienced a high increase at an average annual rate of 35%. Now it is one of the world's largest manufacturers of viscose filament yarn, rayon embroidery thread and hand knitted garments with 3.9 billion RMB total assets and12,000 employees. The domestic market share of these products reached 33% and international market share is 17% in 2006.[3]

There are many outstanding occurrences about technological innovation in this company which break common sense in China. First, in this company the annual R&D expenses as a percentage of sales are 3% to 9% in the past six years, a figure far beyond the average level of 0.2% to 0.5% in China's textile companies. Second, this company benefits dramatically and continually from a technological innovation, which is very easy to be imitated. This unique technological innovation has strongly supported the high growth of this company at an average annual rate of 35% in the past ten years. Third, the proportion of new product to the product categories is over 50%. They have over 100 patents compared with the average level of below 8 of the import and export enterprises in Sichuan province. [4]

There is also incomprehensible phenomenon in this company which breaks consensus of innovation theory. We can hardly find one single successful joint research program with social knowledge infrastructures such as universities and scientific research institutes in the past ten years. The overwhelming majority of technological innovations are from inside of the company. But these introverted innovation strategy successfully supported the prosperous technological innovation activities in Grace especially from 2000 to 2005.

In 2006 we observed a decrease of technological innovation in terms of quality and quantity and a weakening of enthusiasm of the employees towards technological innovation in this firm. However, the production capacity has already reached the limit, combining with the increasingly heat competition in the market and strict restriction of environment protection, Grace are now facing very dangerous situation and very high pressure on sustainable development. Under such condition, the chair and president Feng pointed out that if the technological innovation can't be revived the company has to die. In the Eleventh Five-year-plan he moves for the "second spring of technological innovation" (the "first spring of technological innovation" refers to the prosperous wave of technological innovation from 2000 to 2005). But so far his new goal is still far to reach.

How to avoid or get out of the stagnancy and boost another boom of innovation is of primary importance to Grace's top management. How the intra-firm learning successfully fostered Grace's eight years of technological innovation boom, why the inter-firm learning

[3] Source: Publicity Department, Yibin Grace Group Co., Ltd.

[4] Source: Publicity Department, Yibin Grace Group Co., Ltd.
Report of the Soft Science Project of State Intellectual Property Office of People's Republic China
"Investigation and Case Study of The Situation of Intellectual Property Rights In Sichuan Import & Export Enterprises"

is failed or fruitless, and how the organizational learning evolutes in the past ten years are of great interest to our researchers.

5. CASE ANALYSIS

We tried to analyze the attributes and dynamics of the TIN of Grace in past ten years of its technological innovation. First, we divided the history of Grace's technological innovation into three different stages. Second, we took snapshot for each of these stages by socialgram to give an intuitive image of the TIN in Grace. Third, we detected the attributes and the dynamics of the TIN in Grace by calculating the parameters of the network.

5.1 What stages did technological innovation in Grace go through in the past ten years?

According to our discussion with the managers and VPs, the history of Grace's technological innovation is divided into three stages: 1997-1999, 2000-2005, and 2006 till now.

The first stage is from 1997 to 1999 named as the "elementary stage of technological innovation" of Grace. It has three historical events. The first is the change of top management. The current chair and president Feng Tao was assigned by the local government. The second is the invention of the historically important technology "2S". 2S is a process innovation which makes it possible to double the production at a very low cost. The third is the massive recruitment of 600 new employees. This directly led to a blood-substitution-like organizational change. Most of the current mid-level managers are from this group of people.

The second stage is from 2000 to 2005 named as the "booming stage of technological innovation" of Grace. It is also called by Grace the "first spring of technological innovation". The main characteristics of this stage are the invention of a large number of influential and profitable technologies, and the rapid growth fueled by the prosperous technological innovation. There are two symbolic events: a boom of patenting including the key technology "2S", the establishment of Science and Technology Administration Department and IPR Office (both of them report directly to the president), and the launching and implementation of a policy which heavily reward the actors and activities of technological innovation.

The third stage is from 2006 till now. We name this stage as the "plateau stage of technological innovation" of Grace. The main occurrences are the technological-innovation-fatigue of the employees, the decrease of quality and quantity of technological innovation projects, the lack of technological talents as a results of their move from technological positions to managerial positions.

5.2 How did the TIN of Grace look like over the three stages of technological innovation?

In addition to the use of the concept of social network, we note the following as being important:

1) Nodes which represent actors are considered as interdependent rather than independent autonomous units. Relational ties between nodes are channels for organizational

learning such as improving actions and building competence through better knowledge and understanding.

2）The network in this paper refers to a "network of innovators" (Powell, 2004) in which the nodes are groups of people and organizations, and the ties between them are contractual or informal relations both inside and outside of the company. It is a homogeneous network in contrast with the heterogeneous network---"network of innovation" (Tuomi, 2002) in which the nodes can be both people and technologies.

3）The dynamics of the network refers to the evolving or changing structure of the network itself. We just took three snapshots during this ongoing process of evolution in the ten-year-technological-innovation of the company. We believe that existing network structure can only be properly understood and explained in consideration of the process that led to it.

4）In the case of Grace, the number of the nodes in the TIN didn't change much during the three stages of technological innovation. So under such condition, density and centrality can be reasonably used as a comparative parameter to see the change of the connectedness of the TIN during these periods of time.

5.2.1 Socialgrams of the TIN in Grace

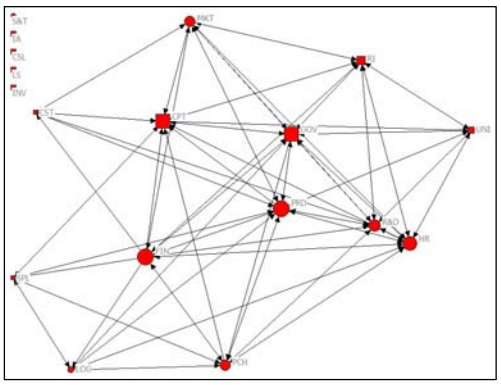


Figure 1. Socialgram of TIN in 1997-1999

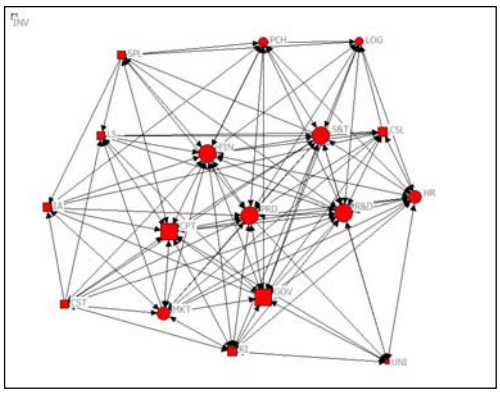


Figure 2. Socialgram of TIN in 2000-2005

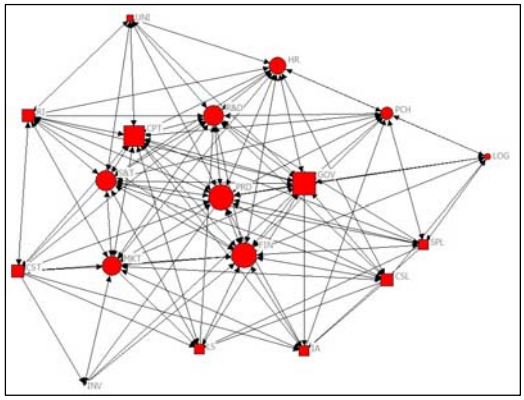


Figure 3. Socialgram of TIN in

2006-now

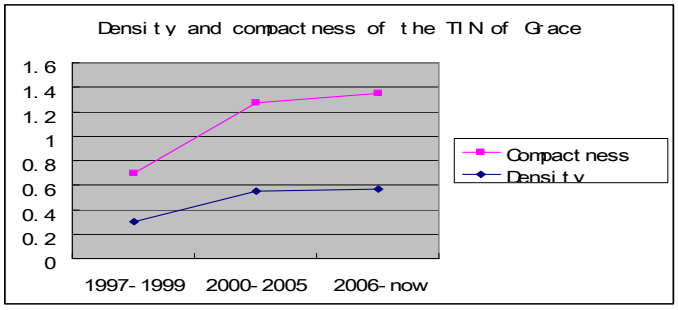
PRD	Production Department	LOG	Logestic Department
FIN	Financial Department	UNI	Universities
CPT	Competitors	SPL	Suppliers
HR	Human Resource	CST	Customers
GOV	Government	S&T	Science &Technology
R&D	R&D Department	INV	Private investors
PCH	Purchasing Department	LS	Legal services
MKT	Marketing Department	CSL	Counsulting companies
RI	Research Institutes	IA	Industrial association

5.2.2 Attributes of the TIN structure of Grace

Four important parameters used in this research to describe the attributes of the TIN structure are density, centrality, betweenness, efficiency, and diversity. Each parameter are grouped several measures with various relative advantages and disadvantages concerning their use.

1. Density

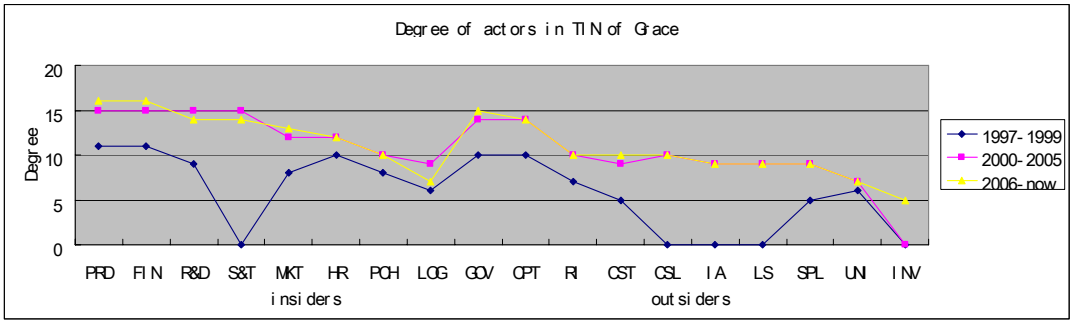
Density is a measure of the connectedness between nodes in a network (Scott, 2000). It is expressed as a proportion of the actual number of ties to the maximum possible number of ties in a network. Scott (2000) pointed out that density is the most widely used and the most possibly abused concept as it is sensible to the size of network. Thereby, it can't be used for comparisons across networks that vary significantly in size.



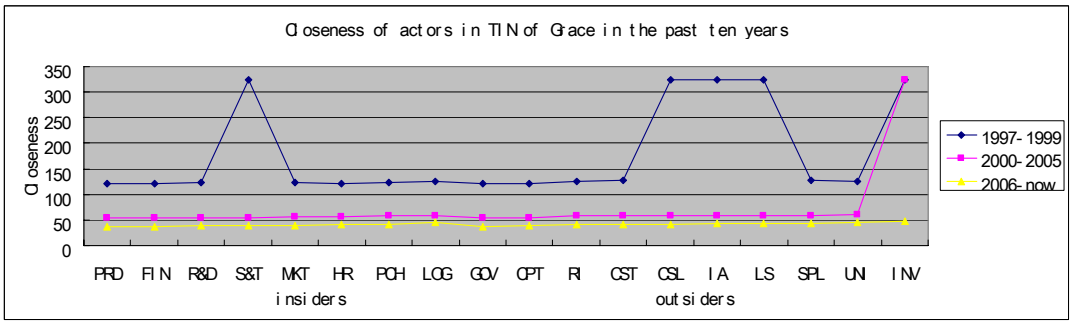
Graph 1. Density and compactness of the TIN of Grace

2. Centrality and betweenness

Centrality includes two concepts: local centrality and global centrality. The local centrality is also called degrees which reflects how a node is connected in the local environment. It is expressed by the number of direct ties with other nodes. The global centrality is also called closeness which reflects to what extent a node is the center of the network. It is expressed by the sum of the distances from a particular node to the other nodes in the network. Centrality also has a disadvantage of density. It makes sense only when doing comparative study between members in the same network or between same size of networks (Scott, 2000).

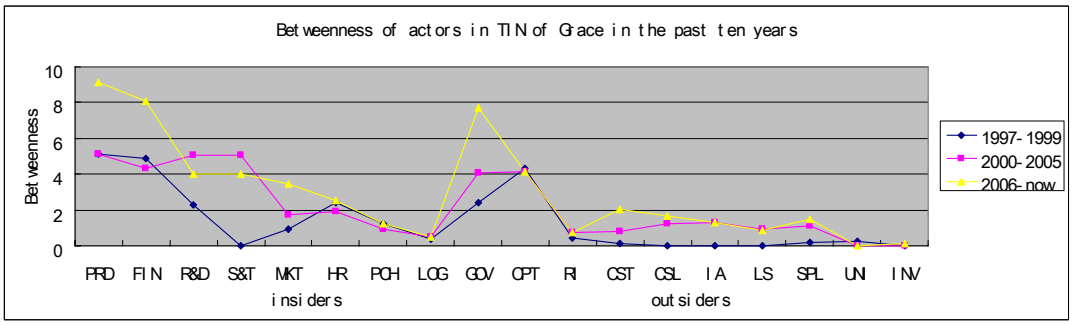


Graph 2. Degree of actors in TIN of Grace



Graph 3. Closeness of actors in TIN of Grace

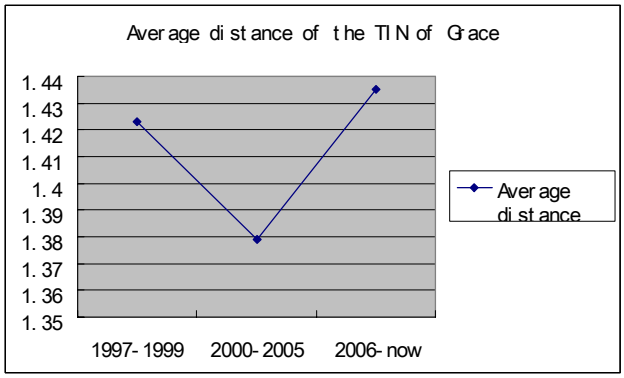
Betweenness measures the extent to which a particular node lies between the other nodes in the network (Freeman, 1979). Even a node is with few ties, it can still play an important intermediary role and consequently be very central to the network.



Graph 4. Betweenness of actors in TIN of Grace

3. Efficiency

Efficiency of a network reflects the extent of difficulty for a node to get access instantly to a large number of different nodes through a relatively small number of ties. It can be measured by the average distance of the network.



Graph 5. Average distance of the TIN of Grace over the past ten years

4. Diversity

Diversity is measured by the number of the nodes which are diverse in nature. In this case, we simply measure diversity of TIN of Grace by the number of the nodes as no actors in the TIN are similar in nature.

Stage	1997-1999	2000-2005	2006-now
The number of nodes	13	18	18

Table1. Number of nodes in TIN of Grace

5.3 How did the TIN of Grace evolve over the three stages of technological innovation?

1. TIN of Grace became much more connected and compacted in the booming stage of technological innovation (2000-2005) compared with the elementary stage (1997-1999) and the connectedness keep going up slightly even when Grace's technological innovation has reached the plateau stage after 2006.

We observed the density increased dramatically from elementary stage to booming stage and then increased slightly in the plateau stage (See Graph1). The same tendency can also be seen in the change of compactness which is represented by distance-based cohesion. At the same time we observed in the reality the performance of technological innovation in Grace became great in the booming stage. New product accounted for 50% of Grace's product categories. The average growth rate of the benefit of technological innovation is 30%. The average growth rate of annual sales is over 35%.

We attribute the great prosperousness of technological innovation in the booming stage to more frequent organizational learning results from a more connected and compacted network where the more number of people cross shorter social distance to learn from each other. When the connectedness of an organizational structure increases, it may indicate an increase of the extent of resource-sharing and cooperation (Powell et al., 1996). Resource-sharing and cooperation is the main activity in organizational learning. Prosperous organizational learning led to improved competence building and then a better economic performance. But it's still too early to say that the entering into the plateau stage of technological innovation is due to the slowdown of the growth of connectedness and compactness.

2. The TIN of Grace got more peripheral actors involved since the booming stage

TIN became bigger (See Table1) and diversified since the booming stage with one insider---the Science and Technological Administration Department (S&T) and four outsiders---industry associations (IA), consulting companies (CSL), legal services (LS), and private investors (INV) got involved.

Among the new comers the S&T Department acts more like a knowledge broker than a knowledge resource for organizational learning in Grace. We observed that it has been in the core of the TIN after its establishment in 2000 (See Table2). In the booming stage, the betweenness of S&T Department is in the highest group. That means the department lies between a big number of departments and organizations. This may give it power of both bridging gaps and controlling information. But in Grace where cooperation is highly recognized and encouraged, S&T Department acted more as a broker to bridge the gap between other actors than a gatekeeper who tryed to control over the others.

The other four newcomers are all outsiders, their participation is crucial for Grace to enrich their knowledge base and foster their organizational learning as these actors are of totally different background and specialty from Grace. The diversity of actors means diversity of knowledge sets for organizational learning.

3. Most of the core members of the TIN in Grace are insiders and most of the outsiders are in the peripheral area over the three stages of technological innovatoin

This composition (See Table2) is in accordance with our observation that in Grace the overwhelming majority of technological innovations are from inside of the company. There were several tries but no even single success in terms of joint R&D program with social knowledge infrastructures such as universities and scientific research institutes in the past ten years. The outsiders played roles of information transferring and knowledge sharing rather than knowledge creation.

Our observation is on the opposite of the widely accepted notions about external cooperation in technological innovation. For instance, a persistent finding from a diverse set of empirical studies is that internal R&D intensity and technological sophistication are positively correlated with both the number and intensity of strategic alliances (Freeman, 1991; Hagedoorn, 1995). But even the research institutes, the competitors, and the government who have been in the core of the TIN of Grace in the past ten years, they have not been the strategic alliances in terms of organizational learning. But this introverted innovation activities successfully created a five-year-boom of technological innovation and let to great economic performance in Grace especially from 2000 to 2005.

We tried to explain this paradox from the external and internal perspective. From the external perspective, we attribute the insider-orientation of Grace's TIN to the distinctive geographic, economic, and cultural environment of Grace. Grace nestled in the Sichuan basin surrounded by mountains in southwest China. Sichuan is far from the economic, political and cultural center of China and Yibin, the city of Grace, is even far from the center of Sichuan. Grace has to pay 500RMB more for transport their products to the customers than their main competitors because of the geographic reason. Sichuan province ranks 25 among the 31 provinces in China in terms of GDP per capital in 2006.[5] In the

[5] Statistical Communique of the People's Republic of China on the 2006 National Economic and Social Development

history, Sichuan is a province which is considered to be geographically secluded, economically disadvantaged, and culturally self-enclosed. Things have been improved in recent years but compared with other regions in China, especially the costal regions, the progress is not enough to create a fundamental change in its situation. So it is relatively difficult for Grace to have enough choice of good consulting companies, legal services, private investors as their strategic partners in Sichuan. It is also difficult to find some successful examples of technological strategic alliance in Sichuan for them to learn from. Further more the introversive culture and self-enclose provincialism restrict Sichuan people's mind and activities to get touch to innovation. From internal perspective, we attribute the success of the TIN of Grace to the company's technological innovation strategy fueled by effective motivating policy, supported by technological-innovation-oriented organizational structure, and based on innovative culture.[6]

Rank	Elementary stage	Booming stage	Plateau stage
1	PRD	PRD	PRD
2	FIN	RD	FIN
3	CPT	ST	GOV
4	HR	FIN	CPT
5	GOV	CPT	RD
6	RD	GOV	ST
7	PCH	HR	MKT
8	MKT	MKT	HR
9	RI	CSL	CST
10	LOG	PCH	CSL
11	UNI	RI	PCH
12	SPL	IA	RI
13	CST	SPL	SPL
14	ST	LAW	IA
15	IA	CST	LAW
16	CSL	LOG	LOG
17	LAW	UNI	UNI
18	INV	INV	INV

Table 2.Ranking of the TIN of Grace in terms of centrality

4. PRD department continually took the most central position in the core of the TIN of Grace over the three stages of technological innovation in the past ten years.

PRD is the core of the core. This position is consonant with the core competence of low-cost-manufacturing based on technological innovation which we identified in our previous

http://www.stats.gov.cn/tjgb/ndtjgb/qgndtjgb/t20070228_402387821.htm

[6] See our working paper for IAMOT2005 conference: Acquiring Competitive Advantage through Technological Innovation- A Case Study of a Textile Company in China

research.[7] The core position of PRD in the TIN of Grace is also supported by another investigation we conducted in Grace about its technological capabilities. In this investigation the contribution of PRD to the company's technological innovation was considered between the advanced level of China and the world.

5. R&D department and S&T department became less central in the plateau stage than in the booming stage.

Their previous important places were taken by the Financial Department and the government (see Table2). There may be two reasons behind. First is about the strategic adjustment in Grace. In 2006 Grace entered into the real estate industry to explore new growth point. In 2007 Grace was chosen as the 10 candidate of a ambitious government project whose intention is to make 100 companies the ten-billion-sales-revenue-enterprise. So they are now searching for other approach than R&D to increase their revenue. Under such condition, we observed a notable decrease of the closeness (See Table 3) which means a decrease of the relative importance of R&D department and S&T department in the TIN of Grace. Second is the number of direct links between other actors in the TIN increased so the betweenness of R&D department and S&T department decreased as the gaps they needed to bridge disappeared. As a matter of fact the degrees of these two departments didn't decrease much, but the betweenness went down obviously (see Table 3).

Stage	**Degree**		**Betweenness**		**Closeness**	
Department	R&D	S&T	R&D	S&T	R&D	S&T
Booming	15	15	5.06	5.06	53	53
Plateau	14	14	3.998	3.998	38	38

Table 3. Change of the centrality of R&D department and S&T department

6. Government became more and more central and important in the TIN of Grace over the three stages of technological innovation.

The government's degree increased across the three stages (See Table 4). This means the government had more and more links with the actors. Its betweenness increased too (See Table 4). What's notable is the jump when it came to the plateau stage. This means they were more likely to be the broker and intermediate for learning among the actors. More actors could be connected via the government. On the one hand, the government can bridge the gaps between the actors. On the other hand it can also then control the information and knowledge flow across the gaps. If the efficiency of government is not good it will directly have bad influence on the efficiency of the whole TIN. The government's closeness continually decreased that means it became closer and closer to the actors (See Table 4). Government play a more and more important role in TIN of Grace.

Stage	**Degree**	**Betweenness**	**Closeness**
Elementary stage	10	2.437	122

[7] See our working paper for CICALICS Workshop 2006: Identifying Core Competence and Assessing Breadth of the Effect of Key Resources on Technological Innovation Based Strategic Capabilities-A Case Study of A Textile Company in China

Booming stage	14	4.08	54
Plateau stage	15	7.69	37

Table 4. Centrality of the government over the three stages

We observed the administration-based and business-based relationship between Grace and the local and provincial government. The supervision-based relationship is a link between Grace and the higher governing authorities and administrative departments, such as the State-owned Property Administration Committee and the Economy Committee at local and provincial levels. The business-based relationship refers to a link which is in terms of business but administrative supervision. We observed that actually these two kinds of relationships are all guanxi-based. Guanxi is a combination of administrative/business relationship plus personal relationship. Grace has very good relationship with government. We observed that from the middle level managers to the VPs called some of the government officials directly by their nickname at the dinner table. They talked about private issues such as their children's education, their relatives' business, and even their personal frustration. That means the relationship between Grace and the government officials is to some extent very personal and guanxi-based. The personal relationship is a complement to the formal relationship. This is good to build mutual trust and understanding. Guanxi makes the relationship stronger and the network more reciprocal. A network with higher reciprocity is usually less hierarchical (Kilduff, 2003). Such network sets up a good environment for organizational learning.

7. Universities were truly sidelined in the TIN of Grace during the three stages in the past ten years

Centrality of universities kept in the lowest group (see Table 2). In sharp contrast, the research institutes kept at the core position of the TIN in Grace even thought their centrality was not that high. In Sichuan province where Grace is located, there is a textile school in Sichuan University, a textile college and many other universities. The outermost position of the universities in Grace's TIN is partly due to a historical reason. In the early time of the booming stage, Grace had invested heavily into a joint R&D project with a famous university in Sichuan but the project failed at last because "the university had different goals" as Grace commented. From then on Grace became reluctant to cooperate with universities but they still have relationship in terms of information sharing and personnel training. But no substantial joint R&D project any more because the mutual trust had been ruined. The outcome of learning processes will depend on social relationships such as trust, authority and recognition. (Lundvall and Christensen, 2004). In this term a link between two actors doesn't necessarily mean a guarantee of productive learning.

8. Competitors played an important role in TIN of Grace

We observed that competitors lay in the core of TIN of Grace from the very beginning. There are three reasons. 1) The first reason is about its legal status. From the 1990s to the early time of the 21st century, almost all the chemical fiber manufacturers are state-owned-companies. Under such condition they used to be gathered for meetings or other activities by the government. 2) The second reason is about the competition. The chemical fiber market is of intensive competition and of high sensitivity to the total volume of production. Any blind expanding and disorderly competition may lead to a crash of the whole industry. So the companies have to cooperate with each other. In fact Grace is the chair of the

Professional Association of Chemical Fiber Industry . 3) The third reason is about patent. Grace's core patent 2S had been infringed by almost all its main competitors. This directly led to a soar of the total production and a slump of profit of the whole industry. After that Grace sued all the pirates and kept checking them at a frequency of twice a month to see if they have any further infringement.[8] So the competitors had a big number of relations with the actors in Grace's TIN.

No matter what the purpose Grace contacts their competitors, there is information and knowledge about technologies transferred, shared or even created. The managers in Grace told us that they really were inspired by what they saw and hear from their competitors when they attended the meeting of the Professional Association of Chemical Fiber Industry, or even when they went to check the infringement of their patent by the competitors.

6. CONCLUSION

1. When the TIN of Grace become more connected, compacted and diversified, the actors interact with more actors of more enriched knowledge background in a more cohesive pattern. Therefore, organizational learning happens in the network become more frequently, closely and productively. The improved organizational learning consequently prospered technological innovation. When Grace came to the plateau stage from the booming stage of technological innovation, the growth rate of density of the TIN decreased. This phenomenon may imply that connectedness, compactness and diversity of the TIN have positive relation with technological innovation. There is also a positive relation between the increase of centrality of actors in the TIN and the increase of technological innovation outcome.

2. When Grace reached plateau stage of technological innovation, efficiency of the TIN which is shown by the average distance obviously decreased. This implies the importance of the TIN's efficiency to the technological innovation. When interaction between actors in the TIN becomes less efficient, technological innovation which highly depends on interactive learning becomes less productive. At the same time the betweenness of the R&D and S&T Department decreased and the betweenness of the government increased. This means the R&D and S&T departments are not as central as before but the government gets more central in the TIN. The change of the betweenness of these three actors may be another reason of the slowing down of Grace's technological innovation.

3. Given the environment of a remote area and underdeveloped economy, the TIN of Grace is relatively introversive. But it still has productive organizational learning and high production of technological innovation provided right technological strategy, innovation-oriented organizational structure, effective motivating policy, and innovative culture.

[8] See our working paper for GLOBELICS2006 conference: Benefiting from Technological Innovation through Patenting Strategy-A Case Study of aTextile Company in China

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